



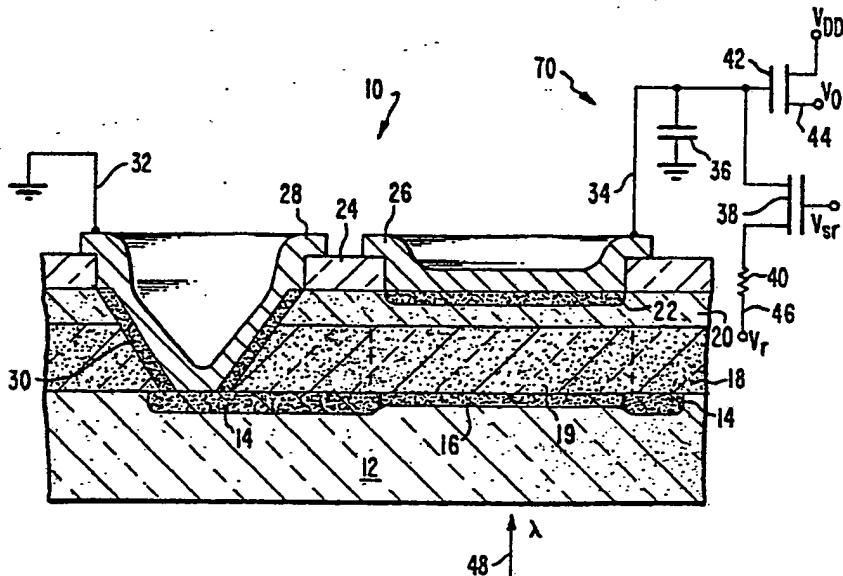
INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ³ : H01L 27/14, 31/08	A1	(11) International Publication Number: WO 83/ 04456 (43) International Publication Date: 22 December 1983 (22.12.83)
(21) International Application Number: PCT/US83/00853 (22) International Filing Date: 31 May 1983 (31.05.83) (31) Priority Application Number: 385,979 (32) Priority Date: 7 June 1982 (07.06.82) (33) Priority Country: US (71) Applicant: HUGHES ARICRAFT COMPANY [US/US]; 200 North Sepulveda Boulevard, Bldg. C2 MS A126, P.O. Box 1042, El Segundo, CA 90245 (US). (72) Inventor: GAALEMA, Stephen, D. ; 2726 Chestnut Avenue, Carlsbad, CA 92008 (US). (74) Agents: ROSENBERG, Gerald, B. et al.; 200 North Sepulveda Boulevard, Bldg. C2 MS A126, P.O. Box 1042, El Segundo, CA 90245 (US).	(81) Designated States: AT (European patent), BE (European patent), CH (European patent), DE (European patent), FR (European patent), GB (European patent), JP, LU (European patent), NL (European patent), SE (European patent). Published <i>With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>	

(54) Title: BACKSIDE ILLUMINATED BLOCKED IMPURITY BAND INFRARED DETECTOR

(57) Abstract

A rear illuminated radiation detector (10) comprising a rear contact (10) adjacent a substrate (12) substantially transparent to incident radiation of a given frequency range, detector (19) and blocking (20) layers overlying said rear contact (16), and a front contact (22) overlying the detector (19) and blocking (20) layers. The layers are disposed so that, through them, the front contact (22) is in electrical contact with the rear contact (16). Radiation (48) may enter the detector layer (19) from the rear, through the substrate (12), thereby permitting the detector (10) to be operated in a backside illuminated mode. Such detectors may be fabricated in highly dense arrays and coupled to either hybrid or monolithic readout structures as required for operation as a focal plane array radiation detector.



Optionally, the front contact (22) may be left exposed so that radiation may enter the detector layer (19) from the front of the radiation detector (10), thereby permitting it to be operated in both backside and frontside illuminated modes.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	LI	Liechtenstein
AU	Australia	LK	Sri Lanka
BE	Belgium	LU	Luxembourg
BR	Brazil	MC	Monaco
CF	Central African Republic	MG	Madagascar
CG	Congo	MR	Mauritania
CH	Switzerland	MW	Malawi
CM	Cameroon	NL	Netherlands
DE	Germany, Federal Republic of	NO	Norway
DK	Denmark	RO	Romania
FI	Finland	SE	Sweden
FR	France	SN	Senegal
GA	Gabon	SU	Soviet Union
GB	United Kingdom	TD	Chad
HU	Hungary	TG	Togo
JP	Japan	US	United States of America
KP	Democratic People's Republic of Korea		

BACKSIDE ILLUMINATED BLOCKED IMPURITY
BAND INFRARED DETECTOR

1

BACKGROUND

The present invention relates generally to radiation detectors and, more specifically, to enhanced sensitivity backside illuminated radiation detectors particularly adaptable for the detection of long wave infrared radiation (LWIR).
5

Naturally, in the design and construction of high quality radiation detectors, the desire is to make the detector as sensitive as possible to incident 10 radiation within a desired range of frequencies. A generally well known cause of limited sensitivity is a generic phenomenon known as dark current. This phenomenon encompasses a number of different mechanisms operating simultaneously, though perhaps independently, 15 within the radiation detector. These mechanisms, however, are similar in that they result in the flow of current through the detector irrespective of whether there is incident radiation. Thus, the flow of current in the absence of meaningful illumination gives rise 20 to the generic term dark current.

Detector sensitivity is lost in direct proportion to the amount of dark current that flows through the detector. Since dark current effectively generates noise in proportion to its current density, significant dark 25 current flow directly results in the reduction of the detector's signal to noise ratio. Thus, the substantial,



1 if not complete, inhibition of any of the constituent
dark current mechanisms will yield a distinct improve-
ment in the sensitivity of the radiation detector.

As an example, a generally known dark current
5 mechanism is thermal charge carrier generation. In
the case of a donor impurity type radiation detector,
electrons are ionized from their associated impurity
atoms by the absorption of thermal energy. These
ionized electrons move from the impurity level to the
10 conduction band of the crystal lattice. They are then
swept by an electric field to the positive radiation
detector electrical contact. The electric field, of
course, is created by a voltage potential difference
applied across the radiation detector. Additional
15 electrons are injected from the negative potential
electrical contact. The net effect, therefore, is a
dark current flowing through the radiation detector
independently of any current induced by incident
radiation.

20 A method of substantially inhibiting dark current
due to the thermal generation mechanism is equally well
known. Since thermal energy is required for the
mechanism to operate, reducing the temperature of the
radiation detector to within a few degrees of absolute
25 zero effectively freezes out the mechanism. Accordingly,
the percentage of impurity band electrons in the con-
duction band due to radiation absorption ionization is
increased, resulting in a greater detector sensitivity
to incident radiation.

30 Another known dark current mechanism is gamma
radiation induced charge carrier generation. Radiation
detectors are naturally designed and constructed so as
to be as insensitive as possible to incident radiation
of all such frequencies that fall outside their parti-
35 cularly desired frequency detection range. However,

1 some percentage of incident radiation of any given
frequency will be absorbed by a practical radiation
detector. Due to the high energy of charge carriers
generated by gamma radiation absorbtion, additional
5 charge carriers are subsequently generated through
electron collisions. This charge carrier multiplication
results in a substantial dark current. Consequently,
gamma generated dark current is of particular concern
in the case of radiation detectors intended for operation
10 in environments subject to significant amounts of gamma
radiation.

This particular sensitivity to gamma radiation is
heightened in the case of most conventional radiation
detectors. Typically, they utilize high volume, low
15 doping density radiation detection regions for the
absorbtion of incident radiation. The low doping
density provides for a low conductivity detection region
as needed to inhibit the ordinary flow of current from
the applied bias voltage potential through the impurity
20 band of the detection region. The high volume of the
detection region compensates for the low doping density
as necessary to maintain an acceptable radiation
absorbtion efficiency. This, however, increases the
sensitivity of the detector to gamma radiation. The
25 high volume of the detection region affords gamma
radiation a greater statistical opportunity to be
absorbed. Consequently, most conventional radiation
detectors operate inaccurately, if at all, in the
presence of significant quantities of gamma radiation.

30 As mentioned above, there are a wide variety of
mechanisms that result in the generation of dark current.
Some of these mechanisms are fairly well understood and
methods of inhibiting their operation have been devised.
Others, including the impurity band conduction mechanism,
35 are less well understood, if at all.



1 It is also desirable, with regard to the design
and construction of high quality radiation detectors,
that they be particularly adaptable to a wide variety
of applications. These applications may range from
5 the simple detection of a given radiation wavelength
to the high resolution imaging of complex radiation
sources. Thus, the radiation detector must be adaptable
for use as a discrete device as well as in high density
10 focal plane arrays (FPA). Further, with regard to its
use in FPA's, the radiation detector must be compatible
with a wide variety of read-out structures, including
hybridized thin film circuitry and monolithic charge
coupled device (CCD) circuitry. The use of a hybrid
readout structure in conjunction with an FPA generally
15 requires that the radiation detector be capable of
operation in a reverse or backside illuminated mode.

SUMMARY OF THE INVENTION

20 It is, therefore, the general purpose of the
present invention to provide a radiation detector that
exhibits an enhanced and particular sensitivity to
incident radiation of a desired frequency range, and
that is easily adaptable to a wide variety of appli-
cations.

25 This is accomplished by providing a rear detector
contact adjacent to the surface of a substrate that is
substantially transparent to radiation of a given fre-
quency range, a detector and an impurity band conduction
blocking layer overlying the rear detector contact,
30 and a front detector contact overlying the detector
and blocking layers. The front detector contact is
further provided so as to be in electrical contact
with the rear detector through a radiation detection
region of the detector layer. This allows the sensing
35 of charge carrier generation due to radiation absorbtion
ionization.



1 Consequently, an advantage of the present invention
is that it possesses a particular and enhanced sensitivity
to incident radiation within its desired frequency
range due to a significant reduction in the radiation
5 detector dark current flow. The detector sensitivity
is particularized through the use of a low volume
detection region, relative to conventional detectors,
that increases its insensitivity to gamma frequency
radiation. The sensitivity to radiation within the
10 desired frequency range is enhanced by the substantial
inhibition of detection region impurity band conduction
through the use of a blocking layer. This particular
and enhanced sensitivity may be displayed over an extended
operating cycle bandwidth due to a decreased detector
15 response time to chopped or pulsed incident radiation.

Another advantage of the present invention is
that it is adaptable to receiving incident radiation
in either a backside illuminated or a frontside
illuminated mode, or both.

20 A further advantage of the present invention is
that it requires only a simple fabrication procedure,
utilizing conventional, well known fabrication steps,
in order to produce a radiation detector.

Still another advantage of the present invention
25 is that a plurality of radiation detectors may be
fabricated on a common substrate for later packaging,
separately, as discrete devices or, without division,
as a monolithic substrate radiation detector focal plane
array.

30 A still further advantage of the present invention
is that very dense radiation detector focal plane
arrays may be easily fabricated. The structure of the
radiation detectors permits the front detector contacts
to be electrically isolated from one another without
35 need for additional fabrication steps or the introduction
of electrical isolation structural features. Further,



1 a single metal contact may be used in common by a
number of radiation detectors to provide electrical
contact to their respective rear detector contacts,
thereby optimizing the use of the front radiation
5 detector surface. Similarly, use of the radiation
detector in its backside illuminated mode also optimizes
the use of the front radiation detector surface by
eliminating the need for frontside radiation transparent
windows.

10 Yet another advantage of the present invention is
that it is easily adaptable for use in radiation detector
arrays utilizing either the monolithic CCD or hybrid
read-out structures that are characteristically used in
focal plane array applications.

15

BRIEF DESCRIPTION OF THE DRAWINGS

Other attendant advantages of the present
invention will become apparent and readily appreciated
as the same becomes better understood by reference to
20 the following detailed description when considered in
connection with the accompanying drawing in which like
reference numerals designate like parts throughout the
figures and wherein:

25 FIG. 1 is a cross-sectional view of a backside
illuminated radiation detector constructed according to
the preferred embodiment of the present invention;

30 FIG. 2 is a cross-sectional view of a frontside
and backside illuminated radiation detector constructed
according to an alternate embodiment of the present
invention;

35 FIG. 3 is a cross-sectional view of a backside
illuminated radiation detector utilizing an alternate
rear contact electrical connection structure constructed
according to an alternate embodiment of the present
invention; and

1 FIG. 4 is a partial top view of a monolithic
substrate radiation detector focal plane array utilizing
radiation detectors of the type shown in FIG. 1 and
adaptable for use with a hybrid read-out structure.

5

DETAILED DESCRIPTION OF THE INVENTION

Radiation detectors constructed according to the present invention may be optimized for a wide variety of applications. In order to facilitate the description of the invention and the understanding of its operation, the radiation detector constructed and optimized for use in the present invention's originally intended mode of operation will be described below. A number of the contemplated variations of the present invention are described thereafter. The descriptions of these embodiments are illustrative of the present invention and provide a basis for the claims which define the scope of the present invention.

Referring now to FIG. 1, a cross-sectional view of a backside illuminated radiation detector, generally indicated by the reference numeral 10, is shown. The radiation detector 10 is intended to operate in the backside illuminated mode and, further, to be particularly sensitive to longwave infrared (LWIR) radiation. Generally, LWIR radiation is considered to be of frequencies corresponding to a wavelength range of approximately 14 to 30 microns. Accordingly, arsenic is used as the primary detector impurity, since its ionization energy roughly corresponds to the wavelength energy of LWIR radiation.

The radiation detector 10 is substantially comprised of a detector layer 18, a blocking layer 20, and front and rear detector contacts 22, 16, respectively, that are formed on a substrate 12. Electrical contact is made to the detector 10 by way of front and rear metal



1 contacts 26, 28. An oxide layer 24 provides electrical
insulation between the metal contacts 26, 28 and portions
of the underlying detector 10. A bias reset/sense
access circuit 70 is associated with the detector 10.
5 LWIR radiation, generally indicated by the arrow 48,
incident on the rear surface of the detector 10 is
permitted to pass through the substrate 12 and the rear
detector contact 16 and into a radiation detection
region 19 of the detector layer 18 wherein its presence
10 is sensed. Accordingly, at least one aspect of the
present invention is its ability to operate effectively
in a backside illuminated mode.

Considering the constituent components in greater
detail, the radiation detector 10 is fabricated on a
15 substrate 12 that is substantially transparent to LWIR
radiation. Preferably, the substrate 12 is boron
doped silicon having a thickness of approximately
500 microns. Although boron impurities typically
absorb some LWIR radiation, substantial transparency is
20 retained by maintaining the impurity concentration below
approximately 1×10^{14} atoms per cubic centimeter. The
orientation of the substrate crystal lattice structure
should be chosen so as to permit standard anisotropic
etching of epitaxial layers grown on the surface of
25 the substrate 12. Preferably, the substrate 12 is
provided with a standard <100> Miller crystal lattice
orientation.

A rear detector contact 16 is formed at the front
surface of the substrate 12. The rear contact 16 is
30 optimized by considering two factors. The first is
that the detector contact 16 should be heavily doped
in order to have a high conductivity and, thereby, act
efficiently as the rear electrical contact to the
radiation detector 10. Second, the rear contact 16
35 should be as thin and as lightly doped a layer as

1 possible so as to not significantly attenuate LWIR
radiation as it passes through. Therefore, the rear
contact 16 should preferably be an ion implanted layer
approximately 0.2 microns thick having an impurity
5 concentration of approximately 5×10^{18} atoms per
cubic centimeter. Again, arsenic is the preferred
impurity in order to prevent unnecessary contamination
of the radiation detector 10.

A rear detector contact grid 14 adjacent to and
10 conductively connected with the rear contact 16, is
also formed at the front surface of the substrate 12.
The rear detector grid 14 acts as a buried conductor
and thus should have a conductivity as high as or higher
than the rear contact 16. However, the contact grid 14
15 is not limited as to either its doping density or
thickness, since it is not required to transmit LWIR
radiation. Preferably then, the grid 14 is an ion
implanted layer approximately 0.4 microns thick having
an arsenic impurity concentration of approximately
20 2×10^{19} atoms per cubic centimeter. The doping
concentration of the detector contact grid 14 should
not, however, be so high as to hinder the eventual
growth of an epitaxial layer thereon. Naturally, the
front surface of the substrate 12 can be annealed
25 following the formation of the detector contact 16 and
detector grid 14 so as to reduce surface defects that
might otherwise inhibit uniform epitaxial layer growth.

A detector layer 18 is formed on the front surface
of the substrate 12 so as to overlie the detector grid 14
30 and contact 16. The portion of the detector layer 18
overlying the rear detector contact 16 substantially
forms the radiation detection region 19 of the radiation
detector 10. The doping density and the thickness of
the detection region 19, as interdependent factors,
35 should be optimized so as to achieve a maximum radiation



1 absorbtion efficiency (typically above 85%). An additional factor that must be considered is that the thickness of the detection region 19 is directly proportional to the ultimate sensitivity of the radiation detector 10 to gamma frequency radiation. This sensitivity is the direct result of an increased statistical chance that gamma radiation will ionize an impurity electron in a thick detection region as compared to a thinner, but heavier doped, detection region 19.

5 Typically, gamma radiation sensitivity is disadvantageous since it causes spurious operation of the detector 10. Considering these factors, the detector layer 18 is preferably a thin arsenic doped, epitaxially grown layer approximately 7 microns thick (generally within

10 an approximate range of 5 to 10 microns thick) having an impurity concentration of approximately 1×10^{18} atoms per cubic centimeter so that the corresponding radiation absorption efficiency is approximately 90% or greater.

15

The blocking layer 20 is formed preferably as an epitaxial layer on the front surface of the detector layer 18. It is thereby interposed between the front detector contact 22 and the detector layer 18. As another aspect of the present invention, the blocking layer 20 is provided within the radiation detector 10 structure to substantially inhibit the operation of a dark current mechanism generally known as impurity band conduction. Briefly, this mechanism involves the effective conduction of impurity band holes through the impurity band of the crystal lattice to the negative potential contact in response to the applied electric field. Since this conduction is completely within the impurity band, an equal number of holes must be injected from the positive voltage potential detector contact 22 in order for current to flow. The injection of holes, however, can be substantially inhibited by interposing

20

25

30

35

1 the blocking layer 20 between the positive potential contact and the detector layer 18, provided that the impurity concentration within the blocking layer 20 is substantially below that of the detector layer 18.

5 This effectively interrupts the conduction path of the impurity band conduction mechanism and, thereby, results in a direct reduction in dark current. Accordingly, the blocking layer 20 preferably has an impurity concentration of less than or equal to 1×10^{15}

10 atoms per cubic centimeter. Arsenic is the preferred impurity simply to prevent the unnecessary contamination of the detector layer 18 with a different impurity. The thickness of the blocking layer 20 need be sufficient only to prevent a direct electrical contact between

15 the front detector contact and the detector layer 18. A preferable blocking layer thickness is 3 microns.

 The front detector contact 22 is formed as a thin, highly conductive layer adjacent to the front surface of the blocking layer 20. Accordingly, the detector front contact 22 is preferably created by low energy ion implantation so as to have an impurity concentration of approximately 1×10^{20} atoms per cubic centimeter. Again, arsenic is the preferred impurity type so as to reduce to the possibility of contaminating the detector layer 18.

 The oxide layer 24, preferably having a thickness of approximately $1,000\text{\AA}$, is formed over the entire front surface of the blocking layer 20. This is to provide a basis for the selective processing necessary to form the radiation detector front and rear metal contacts 26, 28, respectively. Specifically, it allows a particularly positioned window to be opened above a portion of the rear detector contact grid 14. A standard anisotropic etch can then be performed so as to expose a smaller portion of the grid 14. A window is also opened above the front detector contact 22. Since the



1 front contact 22 is immediately exposed thereby, no
additional etching is required. The electrically
separate front and rear metal contacts 26, 28 can be
sputter deposited from the front of the radiation
5 detector 10 so as be in electrical contact with the
front detector contact 22 and the rear detector contact
grid 14, respectively. In order to further simplify
the fabrication of the radiation detector 10, the
oxide layer 24 may be also used as a mask during the
10 ion implantation of the front detector contact 22.
That is, the oxide layer 24 may be formed and portions
of the blocking layer 20 and the rear detector grid 14
exposed prior to the formation of the front detector
contact 22 by ion implantation. The oxide layer 24
15 naturally allows implanted layers to be formed only at
the exposed surfaces of the detector and blocking
layers 18, 20. Thus, a V-groove contact layer 30 is
formed in addition to the front contact 22. The V-groove
contact layer 30 is purely optional within the structure
20 of the radiation detector 10 and is substantially
nonfunctional due to its distance of several times the
thickness of the detector layer 18 (typically times)
from the radiation detection region 19.

25 To operate the radiation detector 10, an electric
field is applied across the detector 10 by placing a
positive voltage potential on the front detector contact
22 relative to the rear detector contact 16. This is
accomplished by the bias reset/sense access circuit 70.
This circuit 70 is typically part of the read-out
30 circuit provided in conjunction with each radiation
detector 10. Although the specific design of bias
reset/sense access circuits may vary significantly,
they must provide essentially the same functions. For
simplicity, the bias reset/sense access circuit used in
35 conjunction with the preferred embodiment of the
present invention will be described.



1 The bias reset/sense access circuit 70 includes
a common lead 32 that connects the rear metal contact 28
to a ground reference voltage potential and a detector
output lead 34 that is interconnected between the
5 front metal contact 26 and a bias capacitor 36, a bias
reset FET 38, and a detector sense access FET 42. The
voltage potential difference is placed across the
radiation detector 10 by providing the bias reset
FET 38 with a conduction enabling detector bias reset
10 signal, V_{sr} . This permits current from a reference
voltage potential, V_r , present on the bias input
lead 46 and limited by a small inherent impedance,
represented by a resistor 40, to charge the bias capa-
citor 36 to the desired radiation detector bias voltage
15 potential. This bias potential must be sufficient to
create a depletion region across substantially the entire
radiation detection region of the detector layer 18.
Typically, a bias voltage potential of between 200 to
300 mv has been found sufficient for use in conjunction
20 with the preferred embodiment of the present invention.
It should be understood that the maximum bias voltage
potential is limited by the thickness of the detector
layer 18 used in any particular radiation detector 10.
The limiting factor is that if the depletion region
25 induced by the bias voltage potential extends into the
front and rear detector contacts 22, 16, a punch-through
breakdown of the radiation detector 10 will result.
Thus, the depletion region should substantially, but
not completely, extend over the thickness of the
30 radiation detection region 19 of the detector layer 18.
Once the bias capacitor 36 has been charged to
its bias voltage potential, the bias reset signal,
 V_{sr} , is removed and the potential difference appearing
across the radiation detector 10 is allowed to vary in
35 proportion to the amount of LWIR radiation 48 incident



1 on the detector 10. That is, LWIR radiation 48 is
transmitted through the substrate 12 and the rear
detector contact 16 and into the radiation detection
region of the detector layer 18. The radiation 48 is
5 substantially absorbed by the arsenic impurity atoms
resulting in the ionization of electrons into the
conduction band of the crystal lattice. The impurity
band holes created within the depleted portion of
the radiation detection region 19 are swept towards
10 the negative potential rear contact 16 under the
influence of the applied electric field. The resulting
current ultimately causes a reduction of the voltage
potential appearing across the bias capacitor 36.
Naturally, the reduction in voltage potential is
15 proportional to the number of impurity band holes
generated which is, in turn, dependent on the intensity
of the LWIR radiation 48 incident on the radiation
detector 10. The reduced voltage potential across the
capacitor 36 is buffered onto the sense output lead 44
20 by the sense voltage output FET 42. The FET 42 acts as
a buffer by being connected as a source follower. That
is, the gate of the FET 42 is connected to the detector
output lead 34 while its drain is connected to a
positive voltage potential, V_{DD} , greater than or equal
25 to the bias reference potential V_r . Thus, the voltage
potential present on the sense output lead 44, the
source of the FET 42, will be a close approximation of
the voltage potential present on the gate of the FET 42.
The voltage present on the sense output lead 44 can
30 therefore be used to effectively sense the voltage
potential appearing across the radiation detector 10.

Referring now to FIG. 2, a cross-sectional view
of a combination frontside and backside illuminated
radiation detector, generally indicated by the reference
35 numeral 50, is shown. The radiation detector 50 is an
alternate embodiment of the present invention differing

1 slightly, though significantly, from the radiation
detector 10 of FIG. 1. In order to enable radiation
to penetrate from the front side of the radiation
detector 50 into the radiation detection region of the
5 detector layer 18, an alternate front detector/metal
contact structure is employed. In particular, the
front detector contact 57 is formed as a thin, highly
conductive layer adjacent to the front surface of the
blocking layer 20. The front detector contact 57 must
10 be substantially transparent to frontside incident
LWIR radiation 56. Accordingly, the impurity concen-
tration and thickness of the front detector contact 57
should be substantially similar to those of the rear
detector contact 16. A front detector contact grid 58
15 is also formed at the front surface of the blocking
layer 20 adjacent to and conductively connected with
the front detector contact 57. Similar to the rear
detector grid 14, the front detector grid 58 functions
as a conductive connection between the front detector
20 contact 57 and the front metal contact 52. Thus, the
impurity concentration and thickness of the front
detector grid 58 should be substantially identical to
those of the rear detector grid 14. The front metal
contact 52 is provided to form an electrical conduction
25 path between the radiation detector 50 and the bias
reset/sense access circuit 70. It is formed, however,
so as to substantially overlap only the front detector
grid 58, thereby leaving exposed the front surface of
the front detector contact 57. The resulting front
30 detector window 54 permits radiation 56, incident on
the frontside of the detector 50, to penetrate through
the front detector contact 57 and the blocking layer 20
and into the radiation detection region 19 of the detector
layer 18. Accordingly, the ability to operate in either
35 a frontside or a backside illuminated mode, or both, is
another aspect of the present invention.



1 It should be clear that either the impurity concentration or the thickness, or both, of the detector layer 18 must be increased in order for the radiation detector 50 to maintain an acceptable radiation absorption efficiency. In the radiation detector 10 of FIG. 1, the front metal contact 26 acts as a reflector for radiation 48 that initially passes through the radiation detection region of the detector layer 18 without being absorbed. This radiation 48 is reflected back 10 through the detector layer 18 so that there is a second opportunity for it to be absorbed. Consequently, the radiation detector 10 of FIG. 1 enjoys a inherently high radiation absorption efficiency. However, in the radiation detector 50 of FIG. 2, the front metal 15 contact 52 can not function significantly as a radiation reflector. Thus, the radiation detector 50 has only a single opportunity to absorb either the backside incident radiation 48 or the frontside incident radiation 56 as it passes through the radiation detection region of 20 the detector layer 18. Naturally, the value of the bias voltage potential placed across the bias capacitor 36 must reflect any change in the thickness of the detector layer 18.

Referring now to FIG. 3, a cross-sectional view of 25 a backside illuminated radiation detector, generally indicated by the reference numeral 60, having a simplified rear metal contact structure is shown. The modified radiation detector 60 is substantially identical to the radiation detector 10 of FIG. 1. It differs, 30 however, in that the rear metal contact structure has been modified to simplify the fabrication of the detector 60. In particular, the procedure is simplified by the complete omission of the etching of the V-groove. Instead, a window is opened in the oxide layer 24 over 35 a portion of the rear detector contact grid 14. A



1 highly conductive rear contact layer 66 is formed
at the exposed surface of the blocking layer 20. The
contact layer 66 should have an impurity concentration
and thickness substantially similar to those of the
5 front detector contact 22. To further simplify the
fabrication of the detector 60, the rear contact layer
66 may be formed concurrently with the front detector
contact 22 followed by the concurrent formation of the
rear metal contact 64 with the front metal contact 26.

10 Conduction between the rear detector contact
grid 14 and the rear contact layer 66 results from
the fact that the grid 14 is inherently at a voltage
potential above that of the contact layer 66.

15 Consequently, the transition region formed at the
junction of the detector layer 18 and the blocking
layer 20, in the vicinity of the contact layer 66,
is significantly narrowed, thereby permitting current
conduction. Naturally, the distance between the front
detector contact 22 and the rear contact layer 66 should
20 be substantially greater (typically times greater)
than the thickness of the blocking layer 20 in order
to prevent undesirable current conduction between the
front contact 22 and the rear contact layer 66.

25 Referring now to FIG. 4, a portion of a monolithic
substrate focal plane array (FPA) is shown. The complete
FPA includes a number of radiation detectors 10 disposed
in a regular matrix array. Although any one of the
above described embodiments of the present invention
can be utilized in an FPA, for simplicity the preferred
30 backside illuminated radiation detector embodiment
(FIG. 1) of the present invention will be described in
conjunction with the FPA shown in FIG. 4. The radiation
detectors 10 utilize a common rear detector contact
grid 14 to provide common electrical connection to a
35 number of rear metal contacts 28 bordering the detector



1 array. In particular, FIG. 4 shows a portion of three
columns 92, 94, 96 of the radiation detector array and
a bordering column 90 of the rear metal contacts 28.
The particular dimensions of the array, including the
5 size and distance separating the radiation detection
regions 19 of the detectors, other than as previously
noted, are not critical. In all cases, however, the
distance between the front detector contacts 22 of
the detectors 10 must be sufficient for the blocking
10 layer 20 to provide electrical isolation thereinbetween.
Typically a distance of 10 microns is sufficient. In the
present case, the distances must naturally be sufficient
to allow mating of the front surface of the FPA to a
read-out structure having a corresponding array of
15 detector output leads 34 and common leads 32. Naturally,
the reset/sense access circuits 70, associated with
each front metal contact 26, are contained in
the read-out structure. The resulting hybridized
structure is thereby a integral unit containing a
20 dense array of radiation detectors 10 intended to
operate in the backside illuminated mode.

A number of other modifications and variations of
the present invention can also be made to optimize the
radiation detector 10 (hereinafter also generally
25 including the alternate embodiment detectors 50, 60)
for a particular application. Naturally, one such
variation can be provided through the selection of the
dopant used in the detector layer 18. For example,
alternate dopants of indium or gallium may be used to
30 adjust the frequency response range of the detector 10
to the infrared range of 3 to 5 microns. Gallium may
also be used for the infrared range of 8 to 14 microns.
Still other dopants may be used to adjust the frequency
response of the radiation detector 10 to various ranges
35 within the electromagnetic spectrum. Consequently,



1 though the above discussion of the several embodiments
of the present inventions focuses on the detection of
LWIR radiation, the invention is not limited to infrared
detectors but to radiation detectors in general.

5 Accordingly, a variation of the present invention
can be achieved by utilizing a P-type impurity for
both of the detector and blocking layers 18, 20, so
as to provide for a P-type radiation detector. The
same principles of operation apply to the radiation
10 detector 10 constructed with P-type impurities as to
the N-type radiation detectors described above.

15 Perhaps a more significant modification of the
radiation detector 10 is the use of an impurity in the
blocking layer 20 having a conductivity type opposite
of that of the impurity used in the detector layer 18.
Although this will inherently increase the possibility
of undesirable impurity contamination of the detector
layer 18, the use of an opposite conductivity type
blocking layer results in an improved detector reaction
20 time to chopped or pulsed incident radiation. That
is, the amount of time required by the detector 10 to
provide an output proportional to the intensity of the
radiation incident thereon, when the incident radiation
is being chopped at a non-negligible duty cycle, is
25 significantly reduced. It is believed that this improved
response time is due to the elimination of trapped
electrons, inherently present in an N-type blocking
layer 20, by the use of a P-type blocking layer 20 in
conjunction with an N-type detector layer 18. Similarly,
30 an improved response time is achieved through the
elimination of trapped holes, inherently present in a
P-type blocking layer 20, by the use of an N-type
blocking layer 20 in conjunction with an N-type detector
layer 18. Consequently, an aspect of the present
35 invention is the provision of a radiation detector 10
having a significantly faster response time.



1 A somewhat more structural modification involves
reversing the order of the detector layer 18 and the
blocking layer 20, with respect to the substrate 12.
This modification permits the radiation detector 10 to
5 be operated from a negative reference voltage potential
relative to the ground reference voltage potential
applied to the rear metal contact 28. However, this
modification results in the loss of the inherent elec-
trical isolation between the front detector contacts
10 22 of adjacent radiation detectors 10 formed on a
common substrate 12. Since the blocking layer 20 has
a fairly low impurity concentration, the resistivity
of the layer 20 is correspondingly high. Thus, by
forming the front detector contacts 22 in the blocking
15 layer 20, substantial electrical isolation is gained
by virtue of the high resistivity of the layer and the
distance between the front detector contacts 22 of
adjacent radiation detectors 10. Formation of the
front detector contacts 22 in the detector layer 18, as
20 implied by the presently suggested modification, would
result in the substantial loss of electrical isolation
due to the significantly lower resistivity of the
detector layer 18.

Finally, the radiation detector 10 can be modified
25 through the use of any one of several different materials
for the substrate 12. These materials may include a
semiconductor crystal, as contemplated by the preferred
embodiment of the present invention, though doped with
any N- or P-type impurity, or a nonsemiconductor
30 material, such as glass or sapphire. The use of any
one of these alternate materials may be for the purpose
of increasing the transparency of the substrate to a
desired radiation frequency range or to afford the
radiation detector 10 with a greater mechanical strength.

1 Thus, a radiation detector having an enhanced sensitivity to incident radiation and that can be easily adapted to a wide variety of applications has been disclosed. Obviously, many modifications and variations of the present invention are possible in light of the above description of the preferred and alternate embodiments. In addition to those modifications listed above, other modifications may include the introduction of impurities into the detector structure by diffusion and the use of conductively doped polysilicon in place of the metal conductors. It should also be clear that, the various processing steps required to fabricate the various embodiments of the detector, all of which are conventional in nature, have not been described in order to not obscure the nature of the present invention.

5 It is therefore to be understood that, within the scope of the appended claims, the present invention may be practiced otherwise than as specifically described.

29

25

49R/BLA

BAD ORIGINAL

CLAIMSWhat is Claimed is:

- 1 1. A radiation detector comprising:
 - a) a substrate having front and rear surfaces, said substrate being transparent to radiation of a given frequency range;
 - b) a rear contact adjacent to the front surface of said substrate;
 - c) a front contact overlying said rear contact;
 - d) a detector layer interposed between said front and rear contacts; and
 - e) a blocking layer interposed between said front and rear contacts, radiation of said given frequency range incident on the rear surface of said substrate being transmitted through said substrate and into said detector layer so that said radiation detector is capable of operating in a backside illuminated mode.
- 1 2. The radiation detector of Claim 1 wherein said blocking layer is adjacent to one of said contacts and said detector layer is adjacent to the other one of said contacts.
- 1 3. The radiation detector of Claim 2 wherein radiation incident on said detector is also transmitted into said detector layer through said front contact, so that said detector is sensitive to both front and rear illuminating radiation.



1 4. The radiation detector of Claim 2 or 3 wherein
said detector layer, said rear contact, and said front
contact are of semiconductor material of a first con-
ductivity type, said detector layer including impurities
5 in sufficient concentration so that substantially all
of the incident radiation passing therethrough is
absorbed and said front and rear contacts including
impurities in sufficient concentration so as to be
highly conductive relative to said detector layer.

1 5. The radiation detector of Claim 4 wherein
said detector layer is sufficiently doped so as to
absorb substantially all of the radiation within
said given frequency range passing therethrough and
5 sufficiently thin so as to be substantially insensitive
to gamma frequency radiation.

1 6. The radiation detector of Claim 5 wherein
said blocking layer is of a semiconductor material of
said first conductivity type having impurities at a
concentration sufficiently low so as to interrupt the
5 flow of charge carriers through the impurity band of
said blocking layer.

1 7. The radiation detector of Claim 5 or 6 wherein
said blocking layer is of a semiconductor material
of a second conductivity type having impurities at a
concentration sufficiently low so as to interrupt the
5 flow of charge carriers through the impurity band of
said blocking layer.

1 8. The radiation detector of Claim 7 wherein
said blocking layer is adjacent to said front contact
and said detector layer is adjacent to said rear
contact.



1/3

Fig. 1.

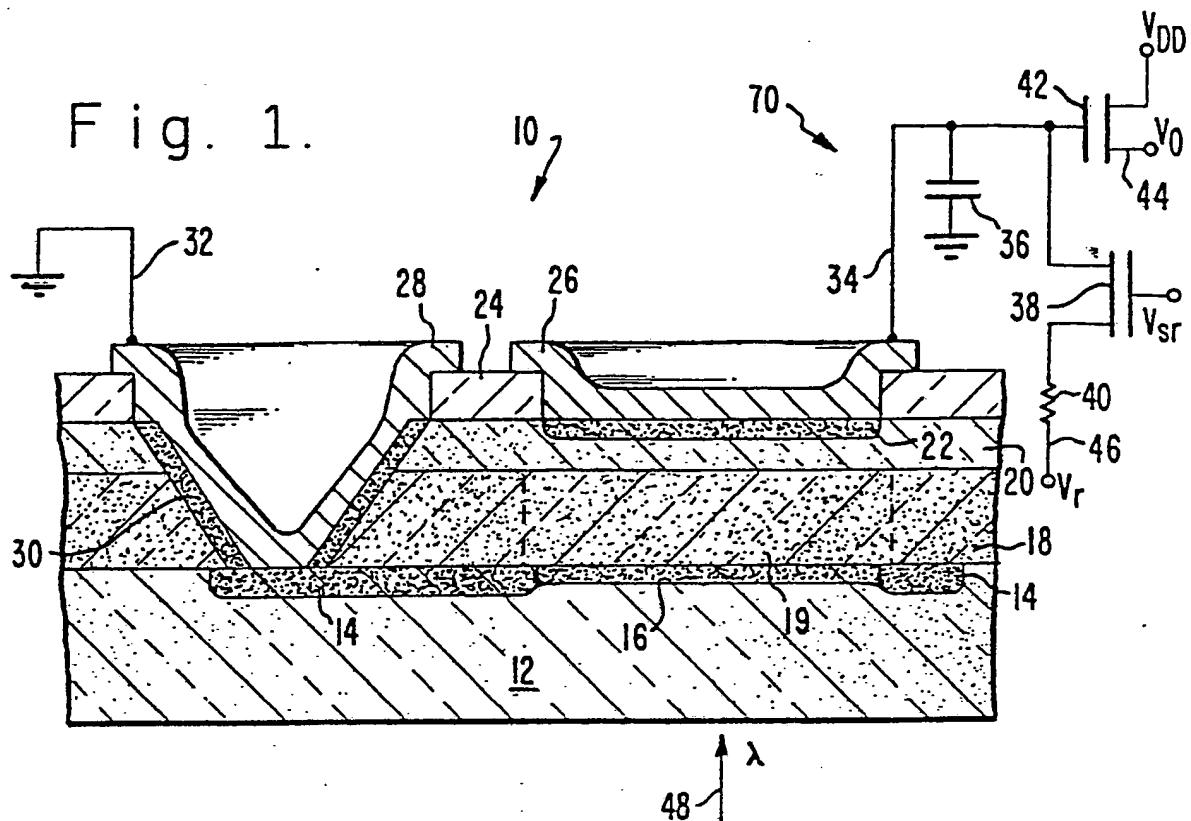
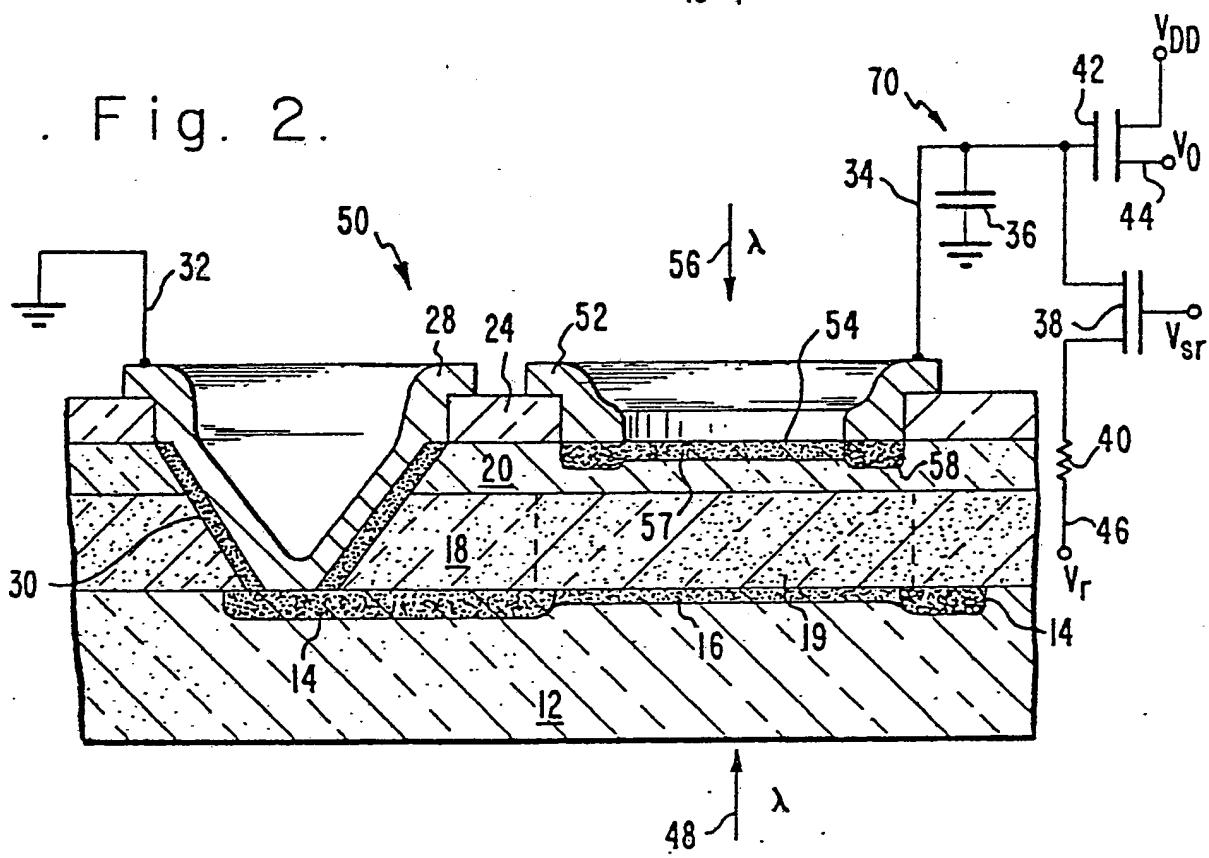


Fig. 2.



2/3

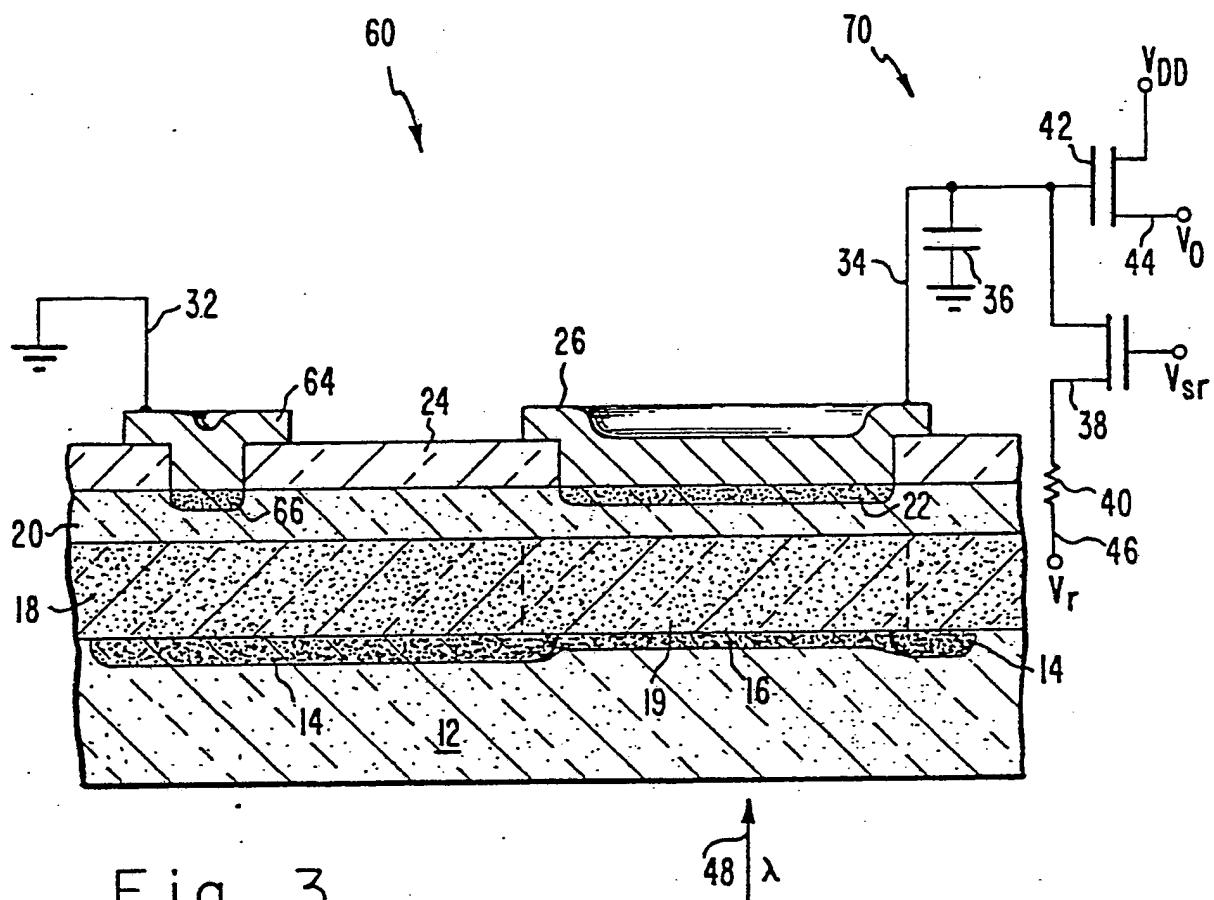


Fig. 3.

3/3

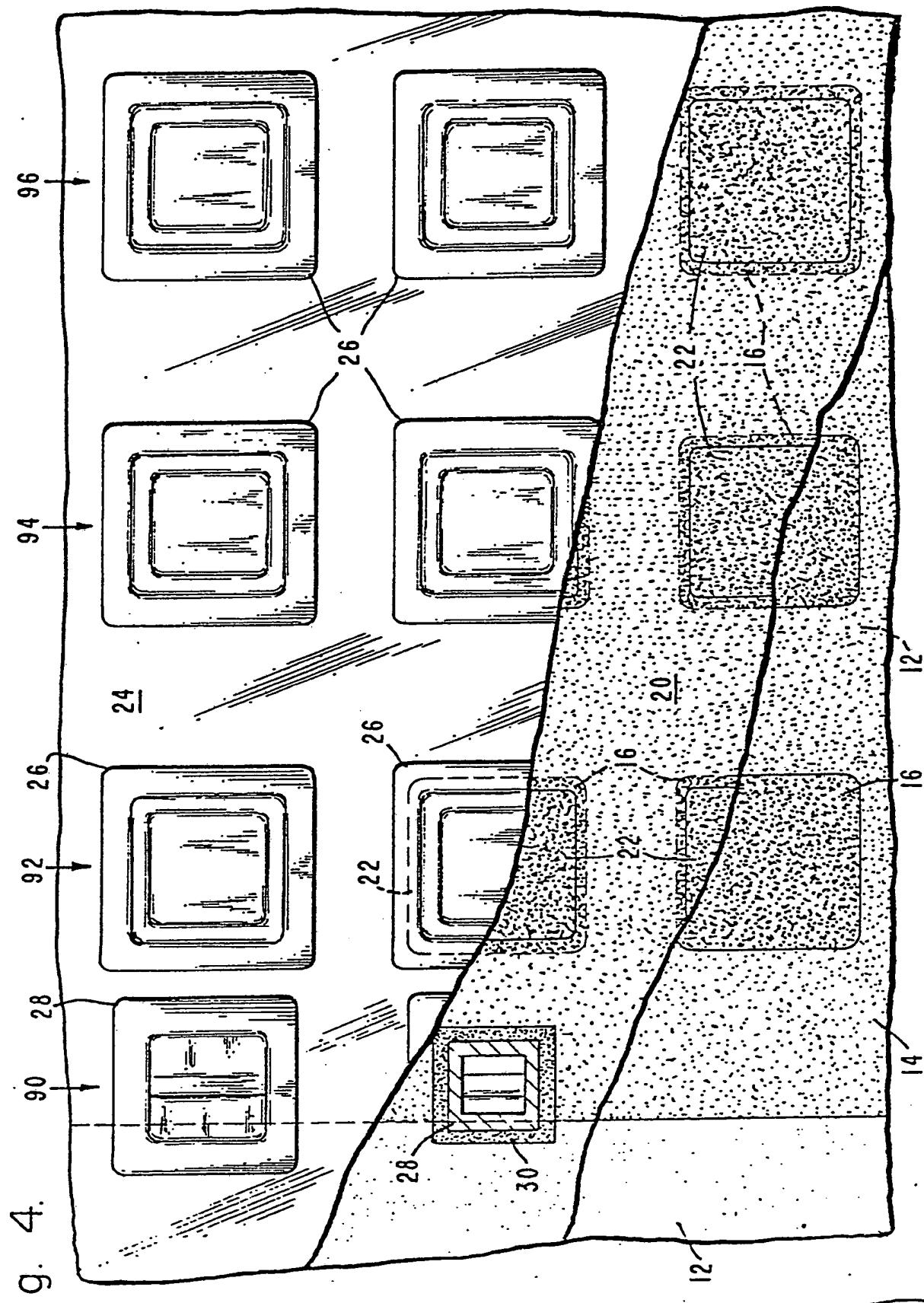


Fig. 4.

INTERNATIONAL SEARCH REPORT

International Application No PCT/US 83/00853

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) ³

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC³: H 01 L 27/14; H 01 L 31/08

II. FIELDS SEARCHED

Minimum Documentation Searched ⁴

Classification System	Classification Symbols
IPC ³	H 01 L
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁵	

III. DOCUMENTS CONSIDERED TO BE RELEVANT ¹⁴

Category ⁶	Citation of Document, ¹⁵ with Indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No. ¹⁸
A	GB, A, 2014783 (MATSUSHITA) 30 August 1979 see figure 1; page 6, lines 40-53 --	1,2
A	Applied Optics, vol. 16, no. 6, June 1977 (New York, US) N. Sclar et al.: "Silicon monolithic infrared detector array", pages 1525-1532 see pages 1526-1531 --	1,4
A	International Electron Devices Meeting, Technical Digest, 4-6 December 1978 (Washington, US) M. Lanir et al. "Backside-illuminated HgCdTe/CdTe mosaics", pages 421-423, see figure 1 --	1
A	US, A, 4197553 (R.M. FINNILA et al.) 8 April 1980 see figure 1; column 4, line 52 - column 6, line 28 -----	1,3,4

* Special categories of cited documents: ¹⁶

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the International filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search ¹⁹

6 October 1983

Date of Mailing of this International Search Report ²⁰

26 OCT. 1983

International Searching Authority ²¹

EUROPEAN PATENT OFFICE

Signature of Authorized Officer ²²

G.L.M. Kruidenberg

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON

INTERNATIONAL APPLICATION NO.

PCT/US 83/00853 (SA 5419)

This Annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 19/10/83

The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB-A- 2014783	30/08/79	FR-A, B 2416554 DE-A, C 2903651 JP-A- 54102992 US-A- 4236829 JP-A- 54103630 JP-A- 55001151 JP-A- 55001152	31/08/79 02/08/79 13/08/79 02/12/80 15/08/79 07/01/80 07/01/80
US-A- 4197553	08/04/80	None	

Date of Dispatch: November 18, 2008

OFFICE ACTION

Patent Application No.: P2004-096060

Cited Documents:

- 1 . Japanese Patent Application Laid-Open No. 2001-339057 *
- 2 . WO03/041174 *
- 3 . WO02/039506 *
- 4 . WO03/096427 *
- 5 . Japanese Published Patent Application, Japanese Translation of PCT international application No. 2002-501679 *
- 6 . Japanese Published Patent Application, Japanese Translation of PCT international application No. S59-501033